ELECTRICAL PROTECTION OF ELECTRONIC ANALOG AND DIGITAL CENTRAL OFFICE EQUIPMENT

CONTENTS

1. GENERAL

1.1 This section provides REA borrowers, consulting engineers and other interested parties with information in the design, installation and operation of REA borrowers' telephone systems. In particular, this section covers electrical protection practices recommended for electronic analog and digital central offices. The practices are also applicable to digital remote switching terminals housed in central office type buildings.

1.2 This section, replacing Issue 5, dated August 1980, has been revised to present the concepts of single-point ground systems. The single-point ground system isolates the electronic switching equipment from all elements of the total central office grounding system except at a single point. This isolation minimizes the flow of potentially damaging currents.

1.3 Electronic switching systems are susceptible to excessive induced transient voltages which may be introduced through incoming circuits, the central office grounding system, or by electrostatic action. The inherent voltage sensitive characteristics of electronic switching systems are due primarily to the fragile nature of semiconductor components and their fast transient response characteristics. Semiconductors typically have low

breakdown voltage ratings and can be permanently damaged by excessive voltage spikes.

1.4 The basic grounding system discussed in this section is designed for application in the single floor office buildings typical in the sytems of REA borrowers. This section may be utilized as described in paragraph 14 to improve protection of electromechanical switching systems that have power and lightning surge related problems.

1.5 The single point grounding system described in this section is designed to meet the protection requirements of most central office equipment manufacturers. No deviation should be made from the described method unless there are compelling reasons for change. (See Paragraph 1.6).

1.6 Some central office equipment manufacturers may request grounding systems exceeding those recommended herein. These might include a rigid, low maximum resistance requirement for the central office ground field or various forms of extraordinary lightning protection. The costs of providing and maintaining these features can be quite high.

1.7 This discussion of central office grounding systems is essentially based on resistance since this is a primary parameter that is readily understood. However, the essential factor in building and switching system protection is the grounding system impedance, especially the reactance component, of the grounding conductors. The general guidelines presented in this practice are based on providing a system having a relatively low overall impedance to the flow of lightning and power fault currents.

2. DEFINITIONS

2.1 The following terms are defined as an aid to understanding their usage in this section. They are terms commonly used for describing telephone central office grounding systems. Different terms have been used by individual manufacturers and operating companies other than those commonly used. Such terms are included in parentheses at the end of each definition, where applicable.

2.2 BUILDING STRUCTURAL GROUND: a ground bond connected to structural steel and/or reinforcing steel rods contained within the building walls, roofs, floors, footings, or foundations.

2.3 CABLE ENTRANCE GROUND BAR (CEGB): a copper ground bar provided for the purpose of terminating incoming telephone cable shields on a common connection point. The bar is normally located close to the entrance location. (CABLE VAULT GROUND BAR).

2.4 CENTRAL OFFICE GROUND FIELD (COGF): a series of interconnected ground rods, buried perimeter cable or a metallic well casing for provision of a low resistance path to earth ground. (CENTRAL OFFICE GROUND GRID).

2.5 COLLOCATED SWITCHING SYSTEM: two or more separate switching systems, at a single location.

2.6 ELECTROSTATIC DISCHARGE (ESD) PROTECTION: protection required to minimize electronic component damage related to static voltage discharges. Static charges are typically generated by moving personnel or moving air in a work area where relative humidity is low.

2.7 FUSE LINK: a length of fine gauge wire in series with a larger gauge wire, for the purpose of "fusing" open during a current-surge condition. This element normally provides protection from currents which could otherwise heat conductors and start fires.

2.8 GREEN WIRE GROUND (GWG): a normally noncurrent carrying conductor provided for the protection of personnel and equipment. The green color code distinguishes the lead from the current carrying grounded conductors (neutrals) which are natural, gray or white. (EQUIPMENT GROUNDING CONDUCTOR)

2.9 GROUND LOOP: ground loops exist when there is more than one electrical path from a point in a circuit to a reference ground connection. Such parallel paths to ground are normally not a problem if associated with the nonsensitive circuitry located outside the IGZ. Ground loops are undesirable for equipment located inside the IGZ.

2.10 GROUND WINDOW BAR (GWB): a copper ground bar provided for the common connection of all equipment located inside the Isolated Ground Zone (IGZ), see paragraph 2.8. (GROUND WINDOW GROUND BAR, MAIN GROUND BAR, GROUND WINDOW SPLICE PLATE).

2.11 INSULATING JOINTS: nonconducting inserts provided at specified points in metal framework of equipment located inside the IGZ. These are provided for the purpose of insulating the IGZ equipment from outside ground connections.

2.12 INTERMEDIATE GROUND BAR (IGB): a copper ground bar, insulated from its support used as a distributing point for a ground wire from the Master Ground Bar (MGB) (see paragraph 2.10) to be connected to several racks or frames of equipment, usually in the non-IGZ area, but <u>not</u> to include battery (+) from the main power board.

2.13 ISOLATED GROUND ZONE (IGZ): a dedicated area within an office building wherein all equipment is electrically insulated from all external grounds except through a single ground connection between the GWB and the MGB. The isolated area should preferably extend a minimum of six feet (1.8 meters) on all sides from the equipment frames and framework and where practical be separated from other equipment by permanent walls. The IGZ will normally house sensitive electronic components. (ISOLATED AREA).

2.14 MAIN DISTRIBUTING FRAME (MDF): a distributing frame where outside plant cables are terminated on vertical protection assemblies. Cable

pairs are also cross-connected on this frame to CO line equipment terminated on horizontal blocks.

2.15 MASTER GROUND BAR (MGB): a copper ground bar used as single point connection for surge producers, surge absorbers, non-IGZ equipment grounds, and IGZ equipment grounds. The MGB is normally non-current carrying and isolated from the building/structural ground.

2.16 MDF GROUND BAR (MDFB): a copper ground bar typically provided at the bottom of the MDF used as the connection point for tip cable shields and MDF protector assemblies. The MDFB may be used as an MGB in small offices. (ENTRANCE CABLE PROTECTOR BAR).

2.17 MDF PROTECTOR ASSEMBLY: an assembly consisting of a protector module and a connector module.

2.18 METALLIC WATER SYSTEM: a public or private water system that includes an outdoor section or buried metallic water pipe at least 10 feet in length and owned by the telephone company.

2.19 MULTIGROUNDED NEUTRAL (MGN): a power distribution system which provides a grounded conductor having multiple direct connections to earth ground. In this system, at least 4 grounds must be provided in each mile of line, not including grounds at individual services. This multiple grounding arrangement provides a very low impedance path to earth ground for the purpose of absorbing lightning and switching surges. It also provides a return path for residual (unbalanced) currents resulting from less than perfect balance on associated three-phase power distribution systems.

2.20 PERSONNEL DISCHARGE PLATES: plates provided in equipment areas containing voltage-sensitive electronic equipment. These plates are connected to ground and are used to discharge body voltages to ground rather than through accidental contact with sensitive electronic components.

2.21 SINGLE POINT GROUNDING: a grounding system utilizing a single point, usually the MGB, to provide a zero reference potential to ground for an entire office switching system. While the voltage at this connection point may rise above zero volts-to-earth-ground under fault conditions, the entire switching system will also rise at the same rate to the same voltage. This helps minimize any circulating currents between switching components during a condition of lightning or power surge.

2.22 SURGE ABSORBERS (A): surge absorbing paths with a low resistance connection to remote earth ground. A grounding element which has a low resistance path to earth ground is considered a primary surge absorber. There are only three primary surge absorbers: (1) the central office ground field, (2) the power system multiground neutral (MGN), and (3) a metallic water system.

2.23 SURGE PRODUCERS (P): connections to metallic sources of lightning and/or power surges. For example, radio/microwave towers, telephone cable shields, telephone cable pairs and power system conductors.

3. SINGLE POINT GROUNDING

3.1 Single-point grounding is based on several related principles. There is a need to control the high voltage differences which are produced between the ends of single conductors such as copper wires and busbars by fast rising electrical surges. Reference Appendix A for a discussion of the voltage effects from rising surge currents.

3.2 Surge potentials need to be equalized through controlled bonding of central office ground elements. Among these ground elements (see Figure 1) are:

a - Surge Producers (P)
b - Surge Absorbers (A)
c - Non-IGZ equipment grounds (N)
d - IGZ equipment grounds (I)

3.3 Single-point grounding is used to reduce voltage differences and control surge currents. The basic elements of a single point grounding system include the following:

3.3.1 A Master Ground Bar (MGB) with connections grouped to confine lightning and power surge activity. This is also the point for establishing a common reference plane, with respect to earth ground, for the entire central office.

3.3.2 A Ground Window Bar (GWB) for establishment of a single local reference point for grounding sensitive electronic equipment within the IGZ. Section I (see paragraph 4) of the MGB provides a single-point termination and ground reference to which the GWB and associated electronic equipment are bonded.

3.3.3 An Isolated Ground Zone (IGZ) surrounding the electronic switch and other sensitive electronic equipment. The IGZ will consistently have the reference to ground as the GWB.

3.4 A high voltage rise can occur between the point of strike and point(s) of dissipation under momentary large surge conditions, such as those resulting from direct or indirect lightning strikes to cable or other outside plant connected to the MGB. The MGB bonding configurations illustrated in Figure 1 and 6 enable high current surges to be concentrated and dissipated through the P and A sections of the bar. This maintains the lowest possible potential at the point of MGB-GWB connection. The connection sequence of P-A-N-I as shown in Figure 1 is very important to the overall protection effectiveness.

3.5 All equipment located within the IGZ electrically floats at essentially the same potential as the GWB when the single-point grounding concept is used. When all switch modules are operating at the same potential, no damaging voltages appear across sensitive components and surge currents are eliminated.

4. MASTER GROUND BAR (MGB)

4.1 The MGB is the hub of the basic central office grounding system used as a common point of connection for the P-surge producers and A-surge absorbers, as well as the equipment grounds for both the N-nonisolated and I-isolated equipment areas. Sizing of ground conductors is discussed in Paragraph 8. The MGB is a copper bar insulated from its support. The MGB may be located either on a wall near the MDF, or on the cable vault wall. In small offices it may be located on the MDF as described in Paragraph 4.2.2. The various connections to the MGB should be tagged or stencilled to identify each as described in Paragraph 8.3.

4.2 Surge Producers (P Section of MGB): The MGB is the preferred connection point for surge producers.

4.2.1 Cable Entrance Ground Bar (CEGB): Cable shields should be bonded directly to a CEGB in offices where a cable vault has been provided. The CEGB is connected by the most direct route to the MGB. The CEGB is a copper bar insulated from its support.

4.2.2 MDF Ground Bar (MDFB): The main frame protector blocks should be bonded directly to the MDFB. A detailed discussion of MDF protection is provided in Paragraph 7. This ground bar is also the bonding point for terminating the MDF end of tip cable shields to ground. The MDFB may be used as the MGB in very small offices where installation of a wall-mounted MGB is impractical. With this application, the bar should be insulated from its support and have sufficient length to provide the connection sequence shown in Figure 1. It is important, that the integrity of all sections of the bar are preserved for the life of the ground bar arrangement. The MDFB may be insulated from its support as required by the manufacturer.

4.2.3 Radio and Microwave Equipment Grounds: Connect all indoor cabinets which are a part of these system(s) directly to the MGB. No connections should be made to the GWB or other central office ironwork. Where the MDFB is used as the MGB, these equipment grounds should be connected to the P section of the bar. Radio/microwave towers are provided with outdoor, dedicated grounding systems. Surge voltages should be equalized by bonding the dedicated grounding system to the central office ground field at a point outside the building for personnel safety and equipment protection. This connection is discussed in Paragraph 4.3.2 - 4.3.2.2.

4.2.4 Standby Power Plant Framework Ground: A connection should be provided between the standby power plant framework and the MGB to equalize framework voltages for safety reasons. When the standby power plant is

located in a separate building from the electronic equipment an earth electrode should be installed and connected to the standby power plant framework.

4.3 Surge Absorbers (The A section of MGB): The MGB is also the preferred connection point for the three primary surge absorbers. They are the power system multigrounded neutral, the central office ground field and the metallic water system. Bonding of the power neutral and water pipe, on the MGB does not replace the requirements of the National Electrical Code for separately bonding the commercial power service.

4.3.1 Multigrounded Neutral (MGN): The MGN with its multiple connections to earth throughout the power system normally has a low resistance to earth ground. Because of this low resistance it may be the most important ground connected to the MGB. The low resistance to earth ground makes it an excellent surge absorber. The MGN may occasionally become a momentary surge producer due to nearby lightning strikes or power system transients. Refer to Paragraph 8 for a discussion of ground system conductor sizes. In any case the ground conductor between the MGN and the MGB should be the same size or larger than the commercial MGN service entrance conductor to the building.

4.3.1.1 Occasionally a non-MGN power system (e.g., delta or unigrounded wye system) will be encountered. A bond is still required between the local power ground electrode and the MGB. Non-MGN systems do not qualify as primary surge absorbers. They must therefore be excluded from the calculations of ground resistance discussed in Paragraph 4.6.1.

4.3.2 Central Office Ground Field: The outdoor portion of the ground conductors connecting the central office ground field to the MGB should be buried a minimum 2.5 ft. (0.76m) below finished soil grade and enter the building through a nonmetallic conduit. The conductor should be placed in a straight line with no splices to reduce the impedance to fast rising surges. See Paragraph 8 for a discussion of ground conductors. When lightning rods and/or radio/microwave towers are provided these should be connected to the central office ground field outside the building as described below.

4.3.2.1 Lightning Rod Ground: Lightning rod systems are grounded via a separate dedicated ground field. A bond should be provided between the central office and lightning rod ground fields, to minimize inductive noise coupling, reduce the chance of flashover, and provide protection for personnel and equipment. The connection point between the two ground fields should be accessible to permit temporary disconnection for earth resistance measurements. The preferred location for this connection is where the conductor between the central office ground field and the MGB is connected to the ground field. An easily accessible, permanent handhole closure is recommended for this connection. The conductors should follow the most direct route with a minimum of bends. See Figures 2 and 6.

4.3.2.2 Radio/Microwave Tower Ground: A bond should be provided between the central office ground field and the radio/microwave tower ground for

the same reasons discussed above. All provisions for this grounding should be identical to those described in Paragraph 4.3.2.1. Where both lightning rod and tower ground systems exist, both systems may be connected to the central office ground field in the same handhole closure.

4.3.3 Central Office Metallic Water System: It is important to bond to the central office metallic water system, where one exists, to comply with National Electrical Code (NEC) requirements. This also provides an additional low resistance connection to earth ground. When no water system is present in the building, this ground connection may be omitted. If the central office water system entrance piping includes at least 10 ft. (3m) of buried metallic pipe in direct contact with earth (1981 NEC Articles 250-80 and 250-81) from either a drilled well or public water system it will qualify as a metallic water system. The water system metallic entrance pipe must also be owned and controlled by the Telephone Company if used as a primary surge absorber. Ground wire connections should be made to the main entrance pipe of the water system. When there is a water meter or insulating joint in the pipe a bypass bonding wire should be installed to insure electrical continuity. Permission from the owner of the water system is required when the pipe on the street side of the meter is not owned by the telephone company or where there is an insulated coupling at the meter. The electrical service will be bonded to the water piping as shown in Figure 6 to comply with Article 250-80 of the National Electrical Code.

4.3.4 Building Structural Ground: A connection should be provided to the building structural ground for earth grounding and potential equalizing safety reasons. This ground is not considered to be a primary surge absorber. A low resistance path to ground is provided by reinforced concrete that is in direct contact with bare earth, such as building footings. Structural steel used in some buildings can have voltage differences from equipment frames installed in the building. This occurs when equipment frames rise in voltage due to current surges through the MGB or when lightning strikes the structure. During building construction, rebars should be lashed to steel column anchor bolts at each floor/roof level. Connection to the steel columns should be made between the nearest accessible point and the MGB. Ground wire connections should be made directly to the rebar during construction of new reinforced concrete buildings containing no steel columns.

4.4 Non-IGZ Grounds (N section of MGB): The N section is primarily a common voltage reference point to which all non-IGZ equipment frames are connected. The single-point grounding system is designed to confine all lightning and surge currents to the P and A sections of the MGB. The connections to the N section prevent voltage differences between equipment racks, etc. in the non-IGZ area. Surge currents and shock hazards for personnel in the building are thereby effectively minimized. All equipment frames, ironwork, and other exposed metallic surfaces that could become energized are bonded to the MGB at this point. The N section is also the connection for equalizing voltages on the positive (+) central office power bus. This connection between the positive (+) battery terminal and the MGB is not normally a d-c power current carrying conductor and is provided only for

equalizing voltage differences.

4.5 IGZ Grounds (I Section of MGB): The I section of the MGB normally should have the least voltage variation of any section along this ground bar. All ground connections to the GWBs are made in this section.

4.6 Ground Resistance Objective: Reasonable effort to meet the objective ground resistance is an important factor in implementing a single-point grounding system. Installation of a perimeter ground around and outside the building foundation perimeter is recommended. Other types of ground fields are acceptable where the ground resistance objective can be met (reference Paragraph 4.6.2).

4.6.1 The combined central office ground resistance from the three primary surge absorbers, as defined in Paragraph 4.3, should be five-ohms or less when measured at the MGB subject to the limitations of Paragraph 4.6.2. Where all three primary surge absorbers are provided at a central office, the five-ohm objective should be met <u>when any two</u> of the grounds are connected. For central office buildings where only two surge absorbers are available, the objective for the central office ground field is five-ohms or less. (See TE&CM Section 802 for a discussion of grounding techniques.)

4.6.2 Establishment of a low resistance ground field can be difficult at the location of some rural central office buildings. The actual measured resistance to remote earth of the ground field provides a guide for determining if it is practical to attempt achieving the five-ohm objective resistance. Where the measured value of the ground field alone is between five-and 25- ohms, further efforts to reduce the resistance is not recommended. The work required to reduce the resistance an additional one- or two-ohms could be very expensive. When the actual measured resistance exceeds 25-ohms additional effort should be made to reduce the resistance. Earth resistivity measurements should be completed at various depths and locations around the building before initiating any reduction effort. Calculation of the approximate anticipated resistance to earth based on the recorded results of the measurements should be completed for various ground configuration and electrode lengths. The results of these calculations will indicate the probability of attaining the objective ground resistance. (Reference TE&CM Section 802).

4.6.2.1 Following are some techniques which may reduce the central office ground field resistance:

a. Attach to building rebar ground.
b. Drive extended or sectional ground rods to a depth of up to 32 ft. (9.75m).
c. Establish a second ground field.
d. Install one or more 6 to 10-inch (15.2 to 25.4 cm) well casings. These should extend below the water table level.

4.6.2.2 Application of chemical soil treatment, as described in TE&CM Section 802, is not recommended. Chemical treatment is not permanent and must periodically be renewed. Where chemically enhanced grounds are used a program should be initiated to measure the ground resistance at six month intervals to insure they are all still effective.

4.6.3 The resistance of the central office ground field should be determined prior to selecting the specific equipment for installation. The manufacturers of equipment should be advised when the five-ohm central office ground field objective cannot be achieved by established methods. Where extraordinary measures must be taken to protect the equipment warranty the added costs should be considered as described in Paragraph 1.6.

5. CENTRAL OFFICE GROUND WINDOW BUSBAR (GWB)

5.1 All equipment grounds that originate inside the IGZ are terminated on the GWB which should preferably be physically located inside the IGZ and insulated from its support. The use of a GWB which is provided by the equipment manufacturer as an integral part of the switching equipment is acceptable. Normally those ground conductors originating inside the IGZ that are terminated on the GWB will be placed by the personnel installing the switching equipment.

5.2 A separate IGZ should be established with its own GWB where additional electronic or digital switching equipment is located in a remote area of the same floor or on another floor of the building.

5.3 Connect each GWB to the MGB with a conductor following the most direct route. This grounding conductor should be 2/0-gauge or coarser copper with a resistance of less than 0.005 ohms. (Reference Paragraph 8) The use of parallel conductors for redundancy is acceptable as required by the manufacturer.

5.4 The conductors terminating on the GWB should be suitably identified as described in Paragraph 8.3.

5.5 The frame grounds of ONLY that switching equipment and associated electrical equipment located INSIDE the IGZ should be connected to the GWB as may be required by the equipment manufacturer. This includes but is not limited to those items described in the following paragraphs.

5.5.1 All metal framework of the switching systems (e.g., frames, cabinets, bays, etc.) should be connected to the GWB. The manufacturer's recommendations for establishing these connections should be followed.

5.5.2 The cable racks, static control ground mats, discharge plates, transmission equipment, and protective grounds of any other IGZ equipment that obtains power from the main power plant should also be connected to the GWB. Any special recommendations from the equipment manufacturer should be complied with.

5.5.3 The manufacturer's instructions on isolation of the battery charger framework ground from the internal positive (+) chassis connection should be followed.

5.5.4 The a-c conductors including the protective ground conductors serving all 120 volt a-c electrical convenience receptacles and all direct wire peripheral equipment, located in the IGZ, should be sized in accordance with normal "green wire" criteria. Each termination point should be tagged to indicate the green wire is a GWB isolated ground wire. The manufacturer's recommendation for the metallic racks within the IGZ will determine how the green wire is handled in the IGZ. The metallic racks may be insulated from the concrete floors and reinforcing steel or connected to it. Routing of the a-c conduit and protective green wire ground in the manner described below insures compliance with National Electrical Code requirements.

5.5.4.1 Racks insulated from building: The conduit carrying 120 volt a-c conductors into the IGZ should be routed to a junction box located adjacent to the GWB. The green wire should be solidly connected to the junction box and a wire connection established between the junction box and the GWB. Use of metallic or non-metallic conduit for extending and bonding the a-c conductors into the IGZ is at the option of the manufacturer. Where metallic conduit is used care should be taken during installation to assure it is insulated from foreign grounds (building structural steel and reinforced concrete members) beyond the GWB. There is no need to install isolated <u>orange</u> convenience receptacles with this configuration since everything beyond the GWB in the IGZ is at GWB ground potential. Isolated a-c ground convenience receptacles may be installed as required by the manufacturer.

5.5.4.2 Racks not insulated from building: The conduit carrying 120 volt a-c conductors into the IGZ should be routed directly to the metallic racks. Since these racks are at the same ground potential as the conduit and green wire by being connected to the reinforced concrete floor there should be no connection to the GWB. Isolated a-c ground convenience receptacles may be installed as required by the manufacturer. Equipment in the IGZ should be isolated from the metallic racks which are not isolated from building grounds.

5.5.5 Where overhead lighting fixtures located in the IGB are an integral part of or are in electrical contact with the equipment frame(s), the associated green protective ground wires should be connected to the GWB isolated ground wire system. For convenience, they may also be connected to the GWB where the connections above do not exist. All fixtures connected to the GWB system need to be isolated from building structural steel and reinforced concrete members. Green wires associated with lighting fixtures having no electrical contact with the equipment frames may be connected in the conventional way to the a-c distribution panel ground.

5.5.6 The protective grounds for teletypewriters, cathode ray tube consoles, test equipment and other a-c powered devices located or used within the IGZ area are normally provided by the green wire leads in the attached

power cords. The green wire pins should not be removed from the 3-wire power cords of such equipment and 2-wire adapters should not be used.

5.5.7 Every precaution should be taken to insure the integrity of the IGZ. No foreign grounds should be permitted to come into contact wit any equipment within the IGZ except through the GWB, except as indicated by the equipment manufacturer.

6. ISOLATED GROUND ZONE (IGZ)

6.1 An isolated ground zone is defined in Paragraph 2.8.

6.1.1 If practical, permanent markers should be placed on the floor to identify the IGZ boundaries. Paint or tape of distinctive color such as orange should be used.

6.1.2 Precautions should be taken to insure that no permanent or temporary ground connections are permitted to cross the IGZ boundary except as defined in Paragraph 5.5.4.2.

6.2 The metal framework associated with digital electronic central office equipment and associated peripheral equipment should be installed and bonded in accordance with the manufacturer's requirements. Some manufacturers require the frames be isolated from the floor while others permit anchoring directly to the floor.

7. MAIN DISTRIBUTING FRAME (MDF)

7.1 Special grounding considerations are required at the MDF to control incoming surges and provide protection for personnel. The design should provide for this with any of the existing or new MDF protectors that are available. The MDF is treated as being outside of the IGZ in all cases.

7.1.1 MDF protector assemblies should be mounted directly on the vertical frame ironwork. The assemblies mounted on each vertical should be interconnected with a #6 copper conductor to provide a low resistance path for surge currents. Each vertical group of protector assemblies should be connected to the MDFB with a #6 copper conductor. Alternate means of connection to the MDFB are acceptable which do not rely on the frame ironwork for conducting surge currents to ground.

7.1.2 The MDFB should be insulated from the ironwork in all cases where it is used as a MGB (paragraph 4.2.2). The MDFB may be insulated from its support as required by the CO manufacturer.

7.1.3 Protective "ground connections" should be provided between the MDFB and frame ironwork for personnel protection regardless of the type protector assemblies used. The protective ground leads should be 14-gauge and less than 12 in. (30 cm) in length. Paint must be thoroughly removed at points of connections to the ironwork. One connection should be provided for

every 35 ft. (10 m) of frame length.

7.1.4 Where the MDFB is used as the MGB in very small offices (Paragraph 4.2.2) the protective "ground connections" (paragraph 7.1.3) should be connected in the N section of the bar. The MDF protector ground should be connected to the P section of the bar.

7.2 Transmission equipment termination and protection: Digital carrier equipment and sensitive electronic pair gain systems should normally be located inside the IGZ. Some carrier equipment has internal gas tubes for bypassing voltage surges to ground. Equipment of this type should be located outside the IGZ. Analog subscriber and station carrier equipment, voice frequency repeaters and loop extenders are normally located outside the IGZ. All equipment frames located outside the IGZ should be grounded through connections at the N section of the MGB. The equipment located inside the IGZ should be grounded to the GWB.

7.2.1 Protectors for all carrier equipment are normally located on the MDF. An exception may be made to this rule. The protectors for some toll carrier entrance cables are mounted in the carrier bays located in a non-IGZ area.

7.2.1.1 The termination of analog and digital type toll carrier systems on the same protector assembly is not advisable. This practice minimizes coupling that can produce analog carrier circuit noise.

7.2.1.2 Shields of intra-office cable connecting the MDF to carrier equipment bays should be open at the MDF end and grounded at one point to the MGB or GWB. This grounding arrangement provides electrostatic shielding and maintains GWB integrity.

7.2.1.3 Separation of the transmit and receive sides of the cable for T-carrier systems should be maintained. This may be accomplished by using compartmental separation or separate transmit and receive cables all the way to the MDF protector assembly. Between that point and the carrier equipment the separation is usually maintained through use of shielded jumpers, separate shielded transmit and receive cables, or multipair cables with individually shielded pairs.

7.3 Entrance and Tip Cables: The most important characteristics of tip cables, from a protection standpoint, are resistance to flammability and ease of termination. They should also be chemically compatible (i.e., should not chemically react) with the outside plant cables. They should be gauged as described in Paragraph 7.3.2.

7.3.1 Most REA accepted polyvinyl chloride (PVC) insulations and jacket formulations used in telephone cables have adequate flame resistance. They can, however, be destructively damaged chemically by cable filling compounds that are in common use. Polypropylene and polyethylene insulation, polyethylene jackets, and some filling compound types will promote combustion.

Use of filled cables in switchboard rooms should be avoided due to fire hazard. Because of these considerations, nonfilled PVC insulated and jacketed cables (or other insulation with equivalent flame resistance) are preferred for use inside central office buildings and for terminations on the MDF. For compatibility reasons, polyethylene grease (low molecular weight polyethylene) and petroleum jelly (petrolatums) filled cables should not be spliced to conductors insulated with PVC. PVC jacketed tip cables currently available are not usually suitable for outdoor use because of their low resistance to ultraviolet attack and their tendency to become brittle at low temperatures.

7.3.2 The recommended precedure, for use with either filled or nonfilled 24-gauge or smaller gauge polypropylene and polyethylene insulated outside plant cables, is to use a special 22-gauge polyethylene insulated PVC covered conductor tip cable with a PVC outer jacket (ALVYN®), or equivalent, in place of PVC insulated. Only those cables accepted by REA that are included in the REA List of Materials should be used. With this arrangement, if the outside cables are filled, the outer PVC covering of the tip cable conductors can be attacked by the filling compound. It may crack in the immediate vicinity of the splice after having been in place for sometime. Tests have shown that the polethylene insulation on the wire beneath the PVC covering will remain intact and retain adequate dielectric strength. This provides an electrically satisfactory splice in spite of the loss of the thin PVC outer layer. The portion of the tip cables run in the office and terminated on the MDF retain their PVC covering and remain flame resistant.

7.3.3 If the first sections of the outside plant cables are coarser than 24-gauge an additional splice would be needed to install a fuse link between the tip cables and each outside plant cable coarser than 24-gauge. Fuse links are typically 24-gauge and have a minimum length of 4 ft. (1.2m) as shown in Figure 3. The additional splices are expensive and undesirable. Therefore, they should be avoided when possible. One means of avoiding the extra splice is to use a 24-gauge entrance cable between the office and riser pole, manhole or pedestal outside the office.

7.3.4 In the event that neither a cable vault nor a splicing trough exists, the outside plant cables should be brought into the central office and spliced to the ALVYN® or equivalent, tip cables as close a practicable to the cable entrance. When this design is used, the entrance of the outside plant cable into the building and the splice itself should be enclosed in a fireproof box mounted on the inner side of the building wall as shown in Figure 4.

7.4 Protection: Incoming cable pairs terminated on MDF protector assemblies should be protected with protector modules. These modules, which connect an arrestor between each cable conductor and ground, effectively limit foreign potentials that will reach the equipment in the office. The modules should contain white coded carbon blocks or orange coded gas tube arrestors that are included in the REA List of Materials. These arrestors breakdown at less than 1000V under surge conditions.

7.4.1 Cable pairs associated with carrier, loop extenders, voice frequency repeaters, special circuits or "stand alone" tone-to-pulse converters should be protected with orange coded gas tube protector modules. This equipment is tested to withstand only the maximum voltage passed by these modules. Past experience with most electronic equipment has shown there is very little margin above the test level. Other types of special high voltage gap protection as recommended by the equipment manufacturer are acceptable.

7.4.2 Electromechanical central office equipment has generally had an adequate dielectric strength margin to withstand more than the maximum voltage passed by listed arrestors. Because of this there have been instances where blue coded carbon block arrestors were used (contrary to REA recommendations) without causing problems. However, there have been reports of electronic equipment failures in these same offices equipped with blue coded arrestors. The replacement of existing blue coded with white coded carbon block arrestors is essential when an existing mainframe is retained for protection of a new electronic digital switch.

7.5 Current Limitation: Mainframe protectors which are included in the "List of Materials Acceptable for use on Telephone Systems of REA Borrowers (Item nm) are capable of carrying, without hazard, the sustained current which may result from commercial a-c power contacts to outside plant cable having 22-gauge or finer wire. There are a number of MDF protectors available on the market which do not have adequate current carrying capability. It is important that the borrower's engineer ascertain that the MDF protectors delivered by the COE contractor are actually on the List of Materials.

7.6 Heat Coils: Since 1966 REA has strongly recommended that MDF protectors be furnished without heat coils. Historically, heat coils were used as protection against current surges. Laboratory tests have proven that heat coils do not protect line relays under the large majority of fault current conditions that can occur in actual telephone systems. Further, heat coils and fuse links offer little, if any, protection for today's electronic switching components. Since heat coils are "high maintenance" items compared to fuse links, the latter are preferred for meeting National Electrical Code objectives in the C.O. Heat coils should not be used with carrier frequency pairs due to high frequency attenuation. The addition of heat coils increases the cost of the telephone system with virtually no protection benefits.

8. GROUND CONDUCTOR SIZING, ROUTING AND TERMINATING

8.1 The point of reference for sizing all protective ground conductors except green wire conductors and dc power conductors is the MGB. To determine the appropriate conductor size first establish the distance between the two points of connection via the desired route (i.e., between the MGB and CEGB). Next refer to Figure 6 to determine the resistance objective between the two points. Finally from Table A find the wire size with a maximum footage for the desired resistance objective equal to or greater than the wire distance between the two points. Use of Table A or calculated resistance

values are permissible in lieu of measurement. The general guidelines in the following paragraphs are also recommended.

8.1.1 The finest recommended conductor size is 6-gauge, except for the 14-gauge protective grounds at the MDF described in paragraph 7.1.3.

8.1.2 The conductor between the MGB and GWB should always be 2/0 gauge or coarser. The suggested size provided in this paragraph pertains to protective ground conductors only - <u>not to d-c power conductors</u>. The maximum resistance of this conductor should be less than 0.005 ohms.

8.1.3 The conductor between the MGB and the neutral ground bar in the a-c service entrance panel board should always be 2/0 or coarser. The maximum resistance of this conductor should not exceed 0.005 ohms.

8.1.4 The maximum conductor resistance from the MGB to the initial point of connection with all surge producers should not exceed 0.01 ohms.

8.1.5 The maximum conductor resistance from the MGB to the point of connection with all surge absorbers should not exceed 0.01 ohms, except as described in Paragraph 8.1.3.

8.1.6 The maximum conductor resistance from the MGB to the point of connection with all equipment grounds should not exceed 0.01 ohms.

8.1.7 Where an intermediate ground bar (IGB) or connection is provided, the 0.01 ohm objective should be divided on either side of the IGB or connection.

8.2 The planning and installation of the wiring is critical to the provision of an effective grounding system. Care should be taken to minimize induction that may appear in grounding system wiring. Recommended guidelines for installation of grounding system conductors include:

8.2.1 Ground conductors should be insulated to permit integrity testing. Conductors should also be free of splices. If splices must be made only compression connectors or exothermic welding should be used.

8.2.2 <u>Ground conductors should be routed in a manner that will avoid sharp or right angle bends. Routes should follow the most direct path with gradual bends to minimize the inductive reactances that tend to impede surge currents and reduce the overall effectiveness of the grounding system.</u>

8.2.3 Ground conductors except the green wires and d.c. power conductors should not be routed closely parallel to other conductors in the office so as to minimize induction of surges into equipment wiring. These conductors should not be routed through cable racks or troughs, or within confines of any iron work.

8.2.4 The ground conductor should only be placed in nonmetallic conduit. If it must be routed through metallic conduit both ends of the conduit should be bonded to the grounding conductor. Further ground conductors should not be encircled with metal clamps. This is essential to eliminate the high inductive reactance that will impede the flow of surge current along the conductor.

8.2.5 Wire-to-wire and wire-to-ground rod connections should be made only with compression connectors or exothermic weld connections. Solder joints should not be used for any central office system grounding connection.

8.2.6 Wire-to-bonding-bar (busbar) connections should be made with lugs that have a compression connectors or exothermic weld connection. The lugs should have bolt-on provisions for the busbar connections using copper bolts and nuts. Periodically, some of the busbar connections may be removed for test purposes.

8.3 It is desirable that the following stencilling and tagging be provided for simplification of maintenance and testing:

8.3.1 Permanent adhesive cable labels or suitable plastic tags should be provided on ground wire leads at all busbars to identify the origin of each conductor.

8.3.2 The location for each ground conductor should be identified on each ground bar by permanent adhesive label or stencilling.

8.3.3 The designated P, A, N and I segments of the MGB should be clearly identified.

8.3.4 Permanent identification tags should be placed on lightning, CO and radio/microwave ground leads at their accessible points of connection to the central office ground field outside the CO building.

9. POWER SERVICE PROTECTION

9.1 The minimum protection for a.c. power serving central office buildings should consist of a suitable arrestor in the electric power secondary circuit. The borrower is responsible for determining that the characteristics of the secondary power arrestor coordinate with the dielectric strength and surge current carrying ability of all items of ac powered equipment in the central office. These items would include heating, air conditioning equipment, etc. This normally means a secondary power arrestor having a surge breakdown not exceeding 1800 volts peak, and a valve device to prevent power follow current. At least one secondary arrestor is available which will breakdown on 1200 volts or less. Lower breakdown arrestors may be more expensive than the 1800 volt arrestor. However, when the condition described in Paragraph 9.3.1 exists with equipment that can withstand 1200 volts, adequate protection may be provided with only a 1200 volt secondary arrestor at less cost than that of the combination.

9.2 In some instances a secondary power arrestor may be provided by the power company to protect its watt-hour meter at the building service entrance. These devices may not be suitable for protecting central office equipment because they are usually designed to coordinate only with the dielectric strength of watt-hour meters (usually 9 to 10 kV). This is normally too high for telephone power equipment.

9.3 The use of a secondary arrestor to protect the a-c power service entering a central office building is strongly recommended. Some secondary arrestors have a rapid response and coordinate readily with normal a-c powered equipment. They may be mounted either at the weather head or at the load center. Others have poorer characteristics and must be mounted at the weather head, with at least 20 ft. (5m) of steel conduit separating the arrestor from the load center to assure proper operation.

9.3.1 If, after the installation of a secondary arrestor, power failures are still experienced from surges on the a-c bus, a supplementary protector; as shown in Figure 5, should be applied to the affected branch circuit. Recommended supplementary protection consists of a maximum duty gas tube in series with self-restoring circuit breakers or an impedance, to prevent the tube from holding over after the surge has passed.

10. RADIO OR MICROWAVE INSTALLATIONS

10.1 Radio or microwave towers which are located on or in close promixmity to CO buildings require special protective considerations. Their height and conductivity increases the probability of a direct lightning strike.

10.2 Details for the protection of the tower and associated equipment are covered in TE&CM 825, Paragraph 5.

10.3 It is important for protection of the central office equipment that the tower grounding system be bonded to the CO grounding system. This connection should be made outside the building as described in Paragraph 4.3.2. Thus a direct strike to the tower should be diverted to the grounding system rather than enter the office.

11. ELECTROSTATIC & ELECTROMAGNETIC FIELD EFFECTS

11.1 Static electricity is the accumulation of stationary electrical charge on a body or conducting medium created by physical motion such as drawing a comb through hair. Even circulating air currents can cause a charge buildup, especially during periods of low humidity. The electrostatic charge is discharged by grounding the charge storing medium.

11.2 Many circuits packs used in electronic or digital switching equipment contain active devices such as field effect transistors (FET), metal oxide semiconductors (MOS) and complementary metal oxide semiconductors (CMOS). These static-sensitive components can be permanently

damaged when voltages higher than their breakdown point are applied to them. The human body can develop and store a charge of up to 40,000 volts by walking across a nonconductive floor during periods of low humidity. Because of this, special provisions should be applied to prevent circuit component damage from this potential hazard when handling printed circuit cards designated by the supplier to be sensitive to static discharge.

11.3 The accumulation of electrostatic discharge by a body may be reduced in a confined area such as a central office by increasing the relative humidity. Body electrostatic accumulation, at 60% relative humidity, is minimal. Even at this excessive humidity level there is no guarantee the electrostatic build up is eliminated. Further, the humidity may also cause equipment contamination, corrosion, or leakage path problems on the printed circuit cards and associated components. Such problems can produce either permanent or intermittent troubles.

11.4 There are two kinds of electrostatic conditions that produce equipment problems; direct arc into the electronic equipment, and radiated energy that reaches circuits through electric and magnetic field coupling. Discharged electrostatic energy can create a localized voltage (electric) field and current (magnetic) field in adjacent circuit cards. Both types of fields can cause permanent equipment damage and/or logic circuit errors.

12. GENERAL ENVIRONMENTAL & HANDLING REQUIREMENTS FOR ELECTROSTATIC - SENSITIVE EQUIPMENT

12.1 Proper environmental and handling considerations for electrostatic sensitive equipment are essential to prevent component damage and switch down time. The general procedures recommended in Paragraphs 12.2 and 12.3 will reduce the probability of equipment damage.

12.2 The following environmental conditions should be provided where possible:

12.2.1 Appropriate relative humidity levels should be maintained since static charges accumulate more readily under very dry climatic conditions. Refer to the equipment manufacturer's relative humidity recommendations.

12.2.2 Adequate air and dust filters should be installed in air ducts.

12.3 The following precautions should be observed when performing building and equipment maintenance procedures:

12.3.1 Grounding straps should be worn when handling printed circuit cards designated by the manufacturer as being susceptible to damage. Refer to the equipment manufacturer's procedures relating to this subject.

12.3.2 Grounded conductive floor tiles or mats should be installed, where required. The conductive floor tile manufacturer's recommendations

should be followed for installation connection to ground, and maintenance of the floor to preserve conductivity.

12.3.3 Printed circuit cards should not be touched or handled by their components or connector pins.

12.3.4 The repair or modification of circuit cards should not be attempted in the local office. Units should be returned to the manufacturer for repair if tests have been made which show that particular cards are defective. An adequate stock of spares should be maintained in proper storage containers.

12.3.5 Conductive printed circuit card containers should be used as recommended by the equipment manufacturer.

12.3.6 Where the Enable/Disable feature is provided and the manufacturer recommends no card should be inserted or removed until the Enable/Disable switch is in the disable position and/or the card slot connection is disabled by software command.

12.3.7 Only the grounded conventional or isolated a-c ground convenience outlets located in the IGZ may be used for operating tools, test equipment and custodial equipment inside the IGZ. Refer to the equipment manufacturer's instructions regarding the use of a-c tools or test equipment in the equipment area.

12.3.8 Steel wool, steel wool pads or dry untreated cloths or mops for floor maintenance should not be used.

12.3.9 Defective fluorescent lighting components should be replaced. These include defective starters, flickering fluorescent tubes,or noisy ballast transformers. Failure to replace these items may introduce noise into power supply lines and systems.

12.4 The following precautions should be observed when operating motor driven devices in the central office building:

12.4.1 All cleaning equipment and motor driven tools should be in good working order.

12.4.2 Motor driven devices should all have grounded 3-conductor cords to bleed-off static charges or brush-noise generated radio frequency transients.

12.4.3 Motors that are not an integral part of the manufacturers switching equipment should not be started, operated or stopped inside the IGZ.

12.4.4 Equipment should be removed from service when adding or removing wire-wrap connections. Where this is not possible, manual or pneumatic wire-wrapping tools with insulated bits should be used.

12.4.5 Tools with Silicon Controlled Rectifier (SCR) motor speed controls should not be used. The SCR can cause transients in the power supply line and generate magnetic fields.

12.5 The following precautions should be observed for magnetic tapes, floppy discs, and other memory devices:

12.5.1 Motor driven equipment should not be located adjacent to tape transports or memory devices. An extra long hose should be used when vacuuming with the cleaner itself located several feet outside of the IGZ.

12.5.2 Magnetic apparatus such as recording tapes and tape transports should not be exposed to the magnetic fields produced by such items, for example, as flashlights, magnetic screwdrivers or electric motors.

12.5.3 Magnetic tapes should be stored in radio frequency tight high mu ferrous metal cabinets to avoid information loss.

13. DISCHARGE PLATES

13.1 For protection of static sensitive equipment, all personnel should fully discharge any static charge on their body before touching or handling any part of the switch. This is especially important in common control areas. Central office personnel when working in the switching area should touch the nearest discharge plate before touching any part of the switch when required by the equipment manufacturer.

13.2 Installation of electrostatic discharge plates should be considered where they have not been provided by the equipment manufacturer. They should not be installed until the manufacturer has been consulted for recommendations on locations and ground connections. The shape and method of attaching the plates should be accomplished in a manner that will not create any hazard to personnel or limit access to the equipment. Personnel discharge plates should be located, where practical, at intervals within an arms length of any maintenance location.

13.3 Supplemental discharge plates may also be provided by:

13.3.1 Hinged metallic doors when they are grounded with a 14-gauge conductor to the building structural steel or the MGB. Conductive paint should be applied to the doors and metallic door knobs should be left bare.

13.3.2 Light switches and a-c power outlets with metallic plates/covers which are electrically connected to the grounded green wire inside the electrical box.

13.4 Warning Signs: Appropriate warning signs should be posted on all equipment area entry doors and inside the CO where they can be easily seen without creating a safety hazard. The signs should be worded to warn personnel of the electrostatic sensistive area and the need for discharging

body static before handling equipment.

14. APPLICATION TO ELECTROMECHANICAL SYSTEMS

14.1 The principles described in this practice may be selectively applied to electromechanical switching systems. It is especially valuable where it has been historically difficult to protect from power and lightning surges. The only principle that should not be applied is the IGZ arrangement unless there is voltage sensitive equipment in the system.

14.2 It is recommended that some provisions of the protection methods described in this practice be applied to all electromechical switching systems.

14.2.1 A connection between the ac neutral ground bar in the ac service entrance panelboard and the MGB should be established.

14.2.2 An earth ground as low as is practical for the area in which the office is located should be provided. (See Paragraph 4.6.)

14.2.3 Bonding should be provided outside of the building between radio/microwave tower grounds, lightning rod grounds and the central office ground fields.

14.2.4 Common bonding of metallic system components should be provided as recommended by the National Electrical Code.

14.2.5 Grounding conductors should be routed as described in Paragraph 8.2.

14.3 Other portions of the protection method may be provided on an optional basis, depending on the specific needs and limitations of the installation.

14.3.1 In electromechanical systems the MGB and the GWB may be combined in a single bar.

14.3.2 The removal of the charger frame ground strap to the positive (+) terminal is optional.

14.3.3 Establishment of a small IGZ may be desirable where there are types of voltage-sensitive electronic equipment requiring special protection. An electronic line concentrator that has a record of protection-related failures might be treated in this manner.

14.4 Where electromechanical equipment is collocated with electronic switching equipment, the electronic equipment should be protected as described in this practice. The electromechanical equipment should be treated as described in paragraph 14.1-14.3 except the Paragraph 14.3.2 option. Further, the equipment should be grounded to the N section of the MGB.

APPENDIX A

VOLTAGE EFFECTS FROM RISING SURGE CURRENTS

1. GENERAL

1.1 This appendix provides a discussion of the voltage effects on grounding conductors from self inductance in the presence of high surge currents with fast rise times. The discussion is designed to provide a better understanding of the basis for some of the general rules relating to routing of grounding conductors in central office buildings.

1.2 Every conductor has self inductance which provides an impedance to lightning and other surges. A significant voltage difference will occur between the ends of a grounding conductor during the period a surge current is flowing. This potential difference should not appear across sensitive electronic equipment. Further points in the overall grounding system, between which the potential can appear, should not be located so personnel can touch both simultaneously.

2. SELF-INDUCTANCE

2.1 The self inductance (Lg) of a solid, round, non-magnetic and straight ground wire in air or plastic conduit may be approximated with:

$$Lg = 0.061\ell \left(\log_e \frac{48\ell}{d} - 0.95\right) \qquad (1)$$

Where: Lg = Self inductance in microhenries (H)
ℓ = Wire length in feet
d = Wire diameter in inches

2.1.1 All grounding connections in a typical small rural central office can probably be made using only #6 (0.162" (0.4cm) diameter) and 2/0 (0.3648" (0.927cm) diameter) conductors. Lengths of 30 ft. (9.1m) might be required for some connections. From equation (1) the self inductance for 30 ft. (9.1m) of #6 wire is 14.9 μH and with 2/0 is 13.4 μH.

2.2 The self inductance (Lg) of a ground wire in steel conduit where ends of conduit are not bonded to wire is given as:

$$Lg = 0.061\ell \left(\log_e \frac{48\ell}{d} - 0.95 + 1200 \log_e \frac{d_1}{d_2}\right) \qquad (2)$$

Where: 1200 = permeability of iron (estimated)
d_1 = outside diameter (OD) of conduit in inches
d_2 = inside diameter (ID) of conduit in inches

2.2.1 The self induction of the 30 ft. (9.1m) lengths of #6 and 2/0 wire encased in unbonded rigid steel conduit with an OD of 1.315in (3.34cm) and ID of 1.049in (2.66cm) may now be determined from equation (2). The self inductance of the #6 wire is 511.2 μH and 2/0 is 509.7 μH.

2.2.2 A grounding conductor 30 ft. (9.1m) long would not likely be placed in steel conduit. A more common use of conduit is for carrying the conductor through a wall via a one foot (0.3m) length. A one foot (0.3m) length of #6 wire through a one foot (0.3m) unbonded rigid steel conduit will have a self inductance of 16.8 μH and 2/0 will have 16.8 μH. The self inductance of one foot (0.3m) of wire in steel conduit is higher than for 30 ft. (9.1m) of bare wire in air.

3. VOLTAGE LEVEL FROM SELF INDUCTANCE

3.1 The calculation of the momentary voltage that will develop across a length of conductor using the conductor self inductance is possible. This voltage is given by the differential relationship:

$$e = L\frac{di}{dt} \qquad (3)$$

Where:

e = voltage
L = inductance (Henries)
di = change in current (Amperes)
dt = change in time (seconds)

3.1.1 Assuming a moderate surge of 2000 peak amperes with a rise time of 10 microsecond through the 30 ft (9.1m) bare wire described in paragraph 2.1.1, from equation (3), the voltage developed across the wire could be:

#6 = 2980 volts
2/0 = 2680 volts

3.1.2 If this wire is placed in unbonded 30 ft (9.1m) rigid conduit as described in Paragraph 2.2.1 the voltage developed would be:

#6 = 102,240 volts
2/0 = 101.940 volts

3.1.3 Study of the example described in Paragraph 2.2.2 where a one foot (0.3m) length of unbonded rigid steel conduit is used to pass the grounding conductor through a wall is more practical. From equation (3) the voltage developed across the one foot (0.3m) conductor length would be 3360 volts for either #6 or 2/0 wire. The voltage developed across one foot (0.3m) of wire in conduit is 13 percent higher than for 30 ft. (9.1m) of bare #6 wire and 25% higher than for 30 ft. (9.1m) of 2/0 wire.

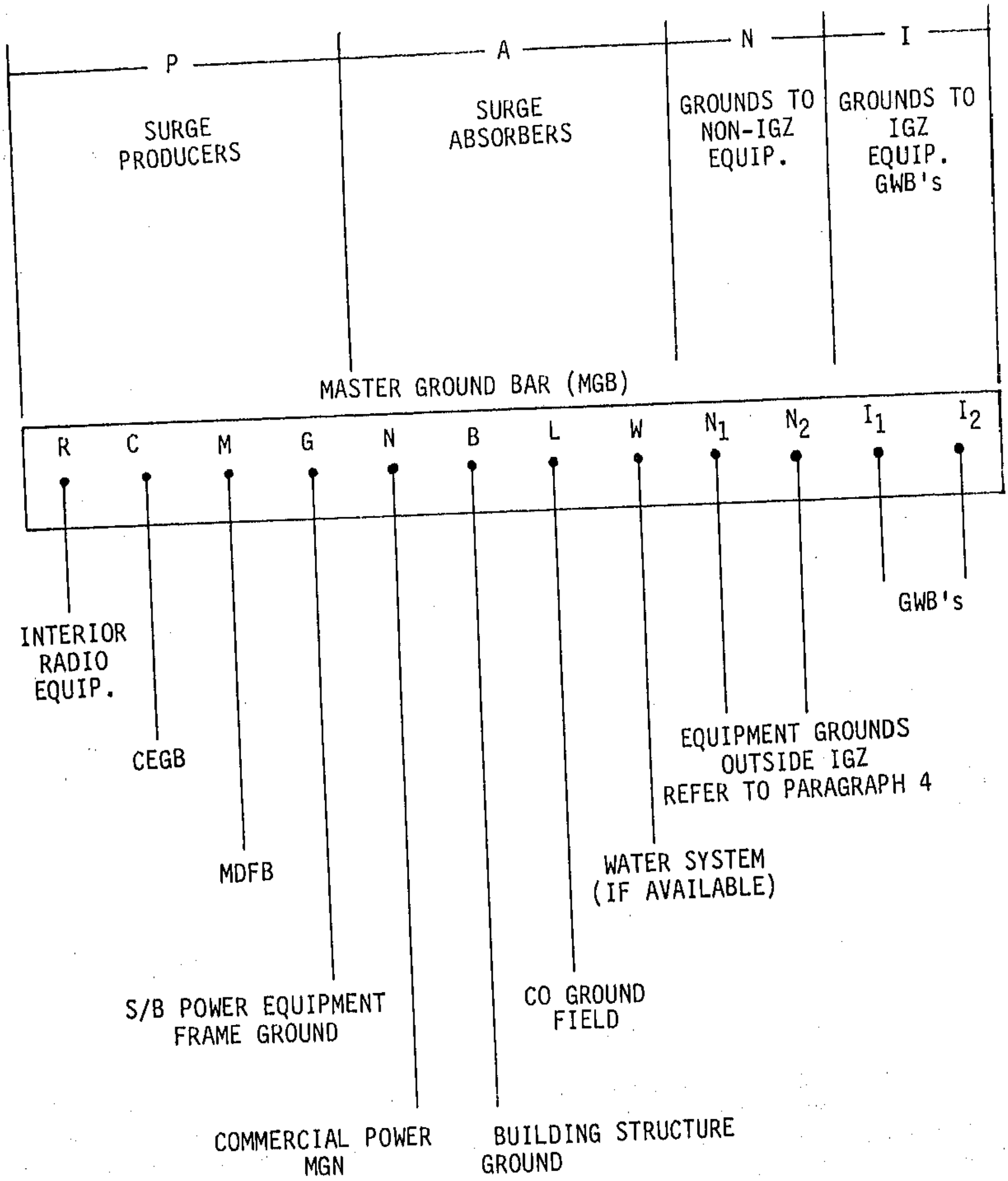


FIGURE 1
MGB - PROTECTION CONFIGURATION

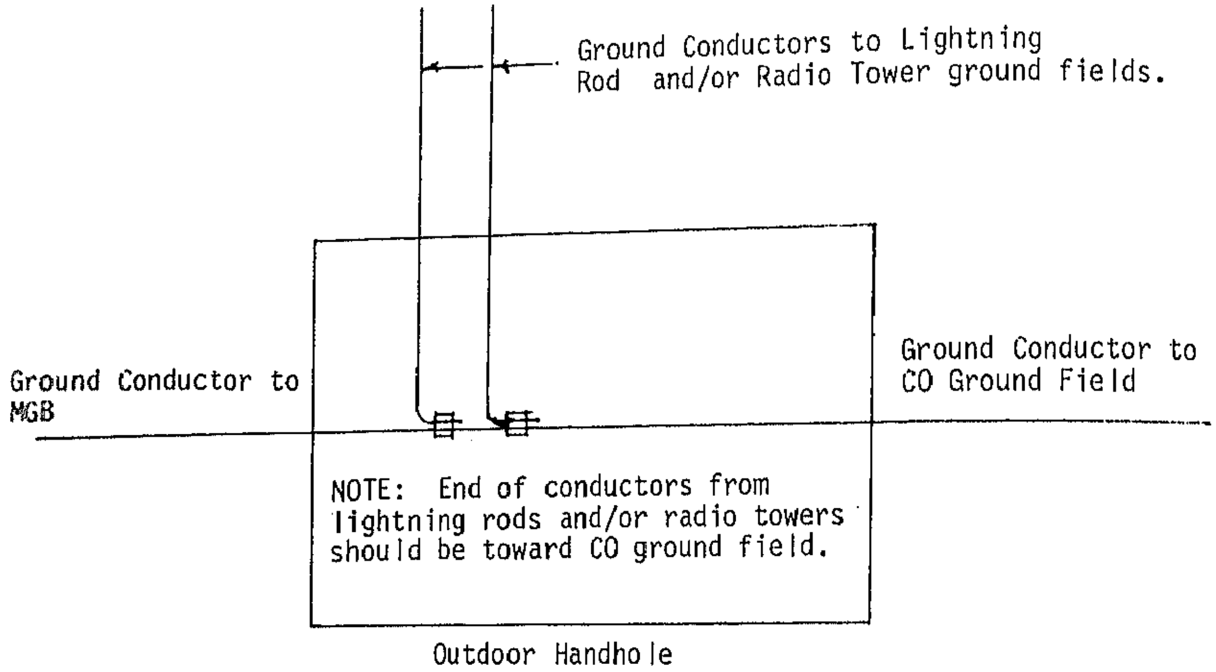


FIGURE 2
Outdoor Ground Conductor Connections

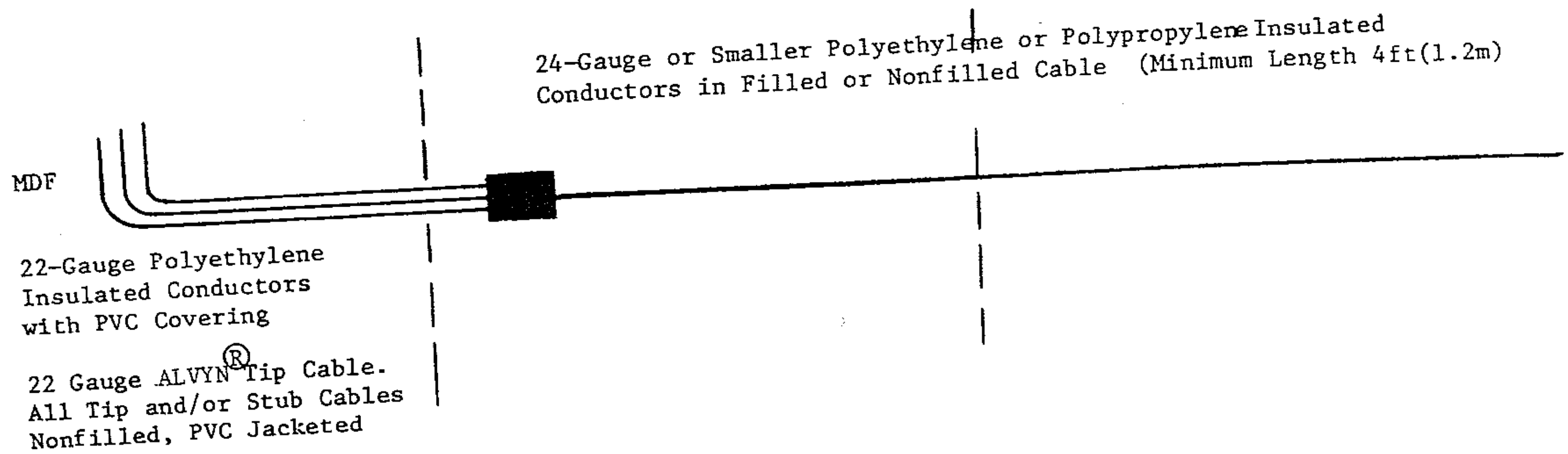


FIGURE 3

Entrance and Tip Cable Arrangements

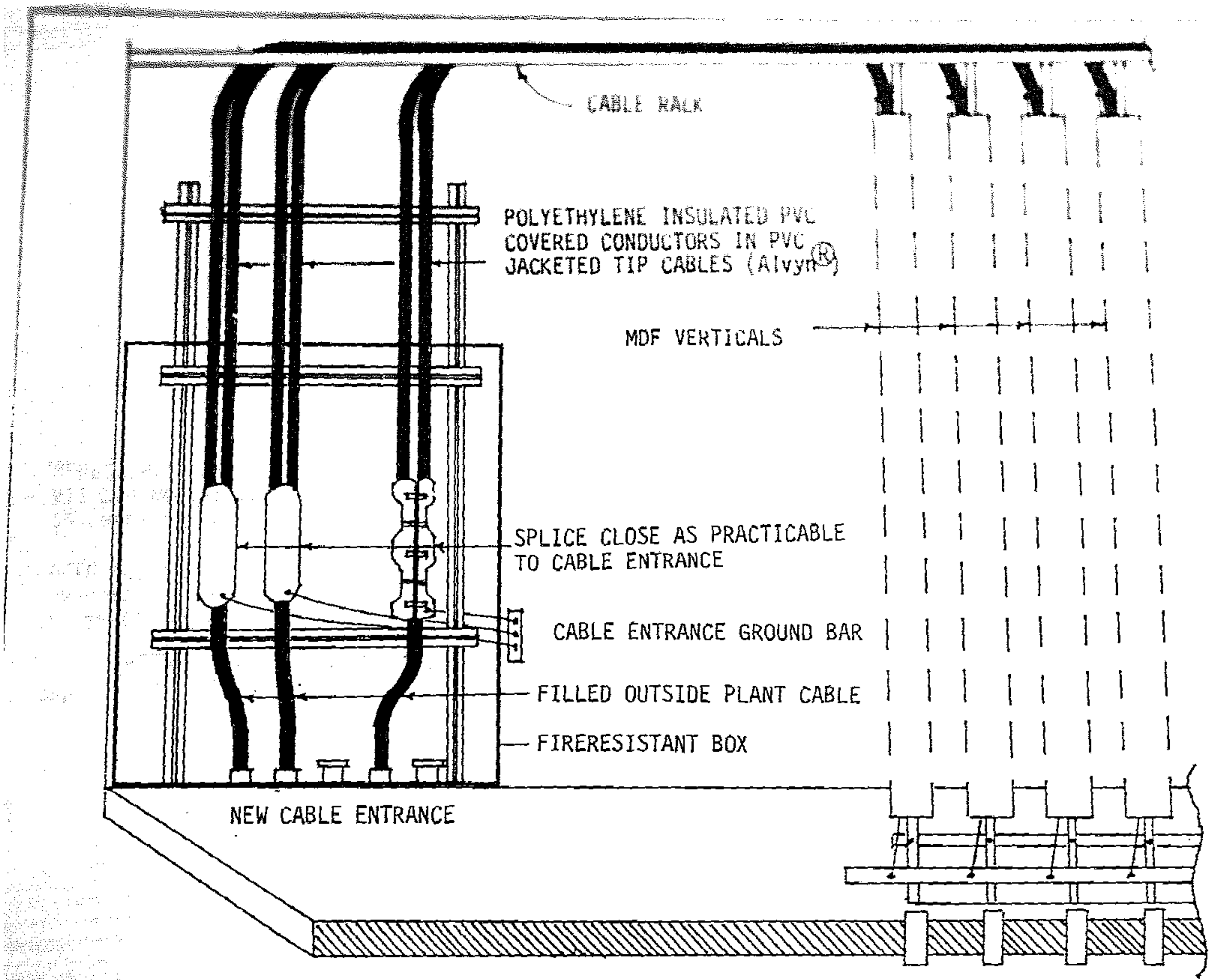
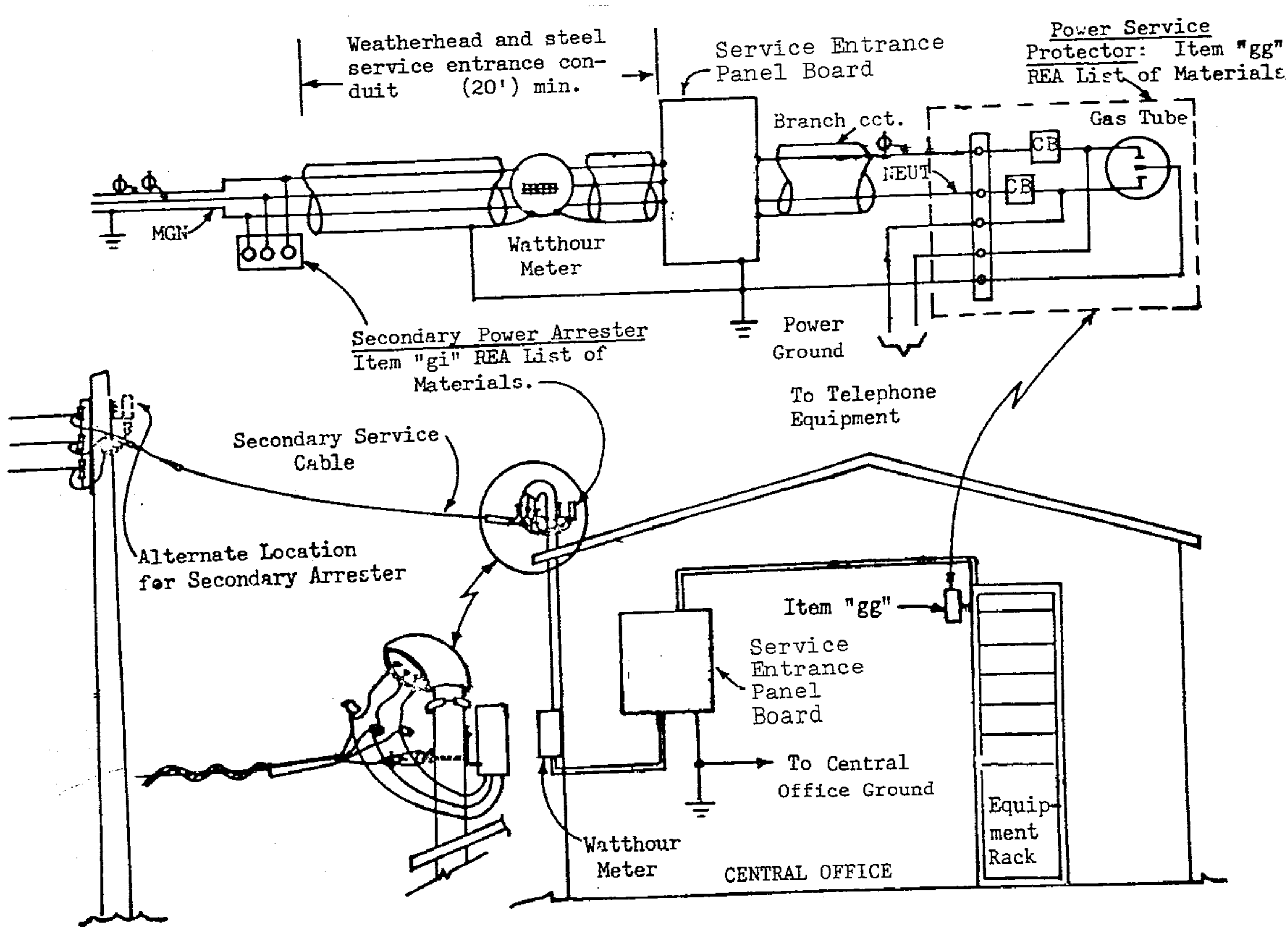


FIGURE 4
CABLE ENTRANCE WITHOUT VAULT



TYPICAL INSTALLATION OF SECONDARY ARRESTER AND BRANCH CIRCUIT POWER SERVICE PROTECTOR

FIGURE 5

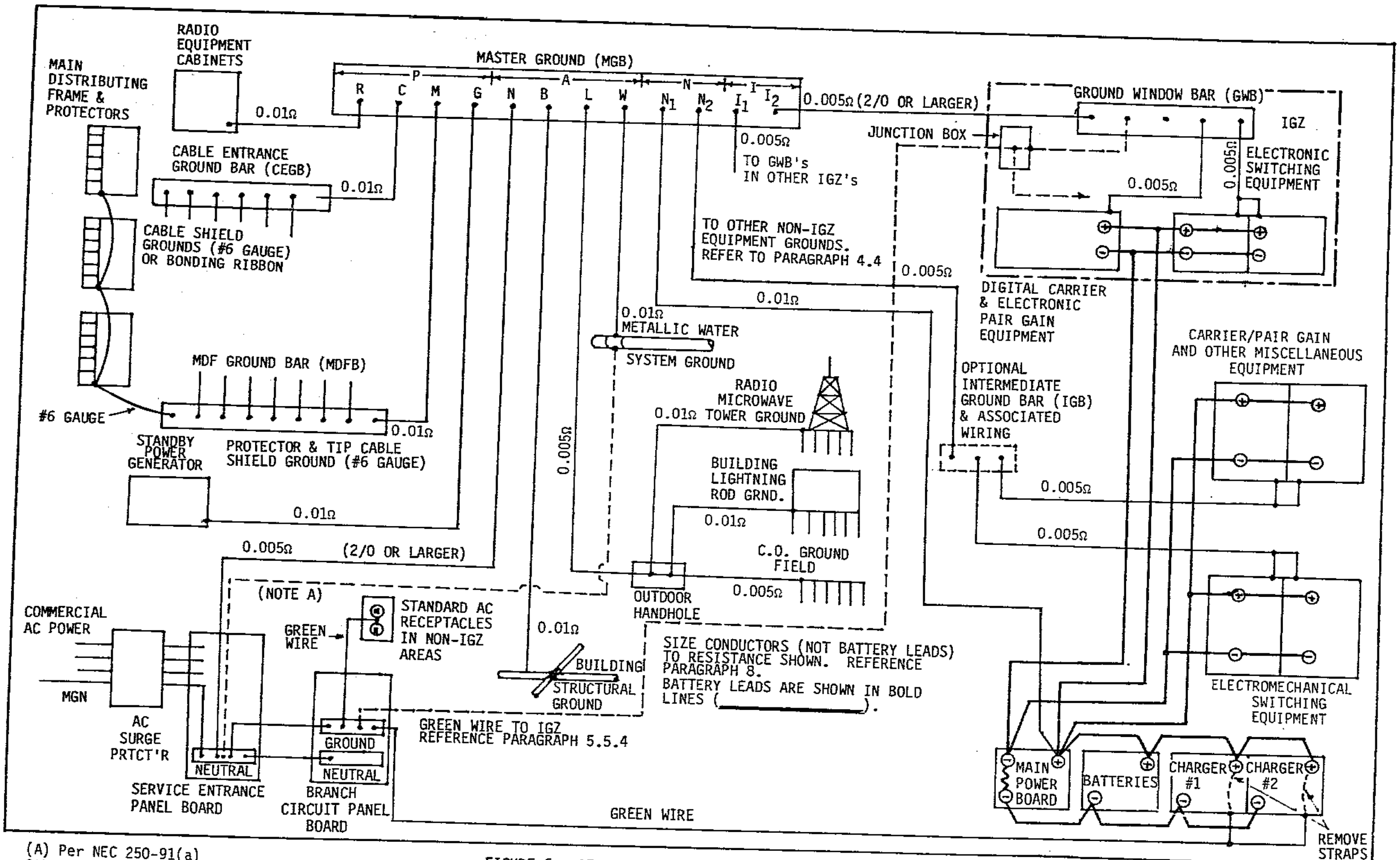


FIGURE 6 - CENTRAL OFFICE PROTECTION GROUNDING

(A) Per NEC 250-91(a)
Other than the wire covered by Note A, grounding connections provided by the electrical contractor during installation of the electrical system have not been included in this drawing.

TABLE A

Characteristics of Bare Copper Wire at 20°C/68°F											
CONDUCTOR SIZE		AWG #6		#4		#3		#2		#1	
dc RESISTANCE		.4110/kf	1.348/km	.2548/kf	.8478/km	.2050/kf	.6726/km	.1625/kf	.5331/km	.1289/kf	.4229/km
Obj. R	0.005Ω	12'	3m	19'	5m	24'	7m	30'	9m	38'	11m
	0.01Ω	24'	7m	38'	11m	48'	14m	61'	18m	77'	23m

Characteristics of Bare Copper Wire at 20°C/68°F											
CONDUCTOR SIZE		AWG 1/0		2/0		3/0		4/0		MCM 250	
dc RESISTANCE		.1022/kf	.3353/km	.0802/kf	.2631/km	.0636/kf	.2087/km	.0505/kf	.1657/km	.0440/kf	.1444/km
Obj. R	0.005Ω	48'	14m	62'	18m	78'	23m	99'	30m	113'	34m
	0.01Ω	97'	29m	124'	38m	157'	47m	198'	60m	227'	69m

Characteristics of Bare Copper Wire at 20°C/68°F											
CONDUCTOR SIZE		MCM 300		350		400		500		750	
dc RESISTANCE		.0367/kf	.1204/km	.0314/kf	.1030/km	.0275/kf	.0902/km	.0220/kf	.0722/km	.0147/kf	.0482/km
Obj. R	0.005Ω	136'	41m	159'	48m	181'	55m	227'	69m	340'	103m
	0.01Ω	272'	83m	318'	97m	363'	110m	454'	138m	680'	207m

MAXIMUM CONDUCTOR LENGTH TO MEET THE

GROUNDING CONDUCTOR RESISTANCE OBJECTIVES

*U.S. GOVERNMENT PRINTING OFFICE : 1983 0-420-931/REA-452